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This process implies an increase in the treatment time, but this is necessary for a SBRT efficiency treatment.

EP-1770

Predictive modeling of respiratory lung motion using single-phase CT and finite-element analysis

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Purpose or Objective: Information regarding lung motion can be highly valuable in modern radiotherapy. During recent years, 4DCT has been used to obtain such required information. This technology is, however, not available to all centres. It is, therefore, desirable to have a predictive model to aid the planning and delivery processes, although this has proven to be a challenging task given the complexities involved. The aim of this work is to develop a biomechanical finite-element model (FEM) of respiratory lung motion that only requires a CT dataset from the end-inhalation phase of the breathing cycle as input.

Material and Methods: A radiology specialist identified 10-18 uniformly-distributed landmarks per lung on each of the end-inhalation and end-exhalation 4DCT datasets for 13 lungs. After segmentation and surface preparation, the first 7 lungs (3 left and 4 right) were used to tune the FEM in the Abaqus FEA software environment. A hyperelastic model with reported parameters was used. Varying magnitudes of pressure were applied to 9 different segments of lung surface. These magnitudes were adjusted until the mean of the squares of the 3D distances between the predicted and actual landmark positions in the end-exhalation CT dataset became < 1 mm. Our tuned FEM was hence obtained. This model was then applied to the study 4DCT datasets comprising 6 lungs (3 left and 3 right). The 3D error vectors between the corresponding landmarks in the end-exhalation phase were calculated and analysed.

Results: Among all landmarks in the 6 lungs in the study set, the mean length of the 3D error vectors was < 2 mm, while the minimum and maximum lengths were 0.1 mm and 7.1 mm, respectively.

Conclusion: Overall, the tuned model shows reasonable accuracy in predicting the end-exhalation position of the landmarks in the lungs, using the input anatomy of only a single end-inhalation phase. These promising results encourage further development and evaluation of the model as well as its tuning over a larger number of patients.

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Biological consequences of dynamic dose interplay in VMAT SBRT lung treatments

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Purpose or Objective: A dynamic dose delivery for stereotactic body radiotherapy (SBRT) of the lung in free breathing can result in dose blurring, interplay or interference effects which may cause a considerable deviation between the prescribed and delivered dose. Here, we investigated the per fraction dose effects by high-spatial resolution measurements.

Material and Methods: GafChromic EBT3 film measurements were carried out in the isocenter plane of a 3 cm diameter tumor in a movable cylindrical cedar lung insert (Quasar phantom). The motion was in the cranial-caudal direction. Motion frequencies were 10 and 15 breaths per minute (bpm), and amplitudes were 10 and 20 mm. Volumetric modulated arc therapy (VMAT) plans for both 6 MV (600 MU/min) and 6 MV flattening filter free (FFF) (1400 MU/min) beams were created for each amplitude. The gross tumor volume including motion (GTV-IM) generated from a most intensive projection of a 4D CT, was prescribed a mean dose of 22.5 Gy. The GTV-IM was enclosed by the 90 % isodose. The motion effects on the GTV-IM were quantified biologically using the generalized equivalent uniform dose (gEUD, a=-10), and dosimetrically by the mean (Dmean) and minimum dose (Dmin). All deviations are given relative to the corresponding planned parameters. Static measurements were performed for each beam and amplitude and served as a baseline.

Results: For the static 10 mm amplitude cases, the relative deviation in gEUD was +0.2% (6 MV) and -1.6 % (6 MV FFF), Dmean = 0.4 and -0.7%, and, Dmin = 1.6 and – 3.5%. For the 10 and 15 bpm and 10 mm amplitude, the reduction in the gEUD ranged between -1.8 and -3.2%. A similar trend in Dmean between -0.8 and -2.6% was observed and Dmin about -10%. The largest relative reduction in gEUD of -7.5% was observed for the 20 mm amplitude and 15bpm for the 6 MV FFF beam. Dmean and Dmin were -4.2 and -21.4% for this case, respectively.

Conclusion: This phantom study indicates that VMAT treatment in free breathing for lung SBRT tumors could lead to 3% under dosage in tumor gEUD for a motion amplitude of 10 mm and 7.5% for a 20 mm amplitude. Tumor movements of more than 10 mm for this treatment technique should consequently be avoided.

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Comparison of dynamic 2D MRI with 4DCT lung tumor volumes for accurate real time imaging on linac-MR

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Purpose or Objective: The hybrid linac MR system is capable of acquiring 2D images at 4 frames per second during radiation delivery. Moving lung tumours can potentially be localized, in real time, by automatic contouring of these images, allowing radiation to “track” the tumour. This study aimed to compare the accuracy of the dynamic 2D MRI of a linac-MR for lung tumour delineation to 4-dimensional computed tomography (4DCT), the current standard for radiotherapy planning for lung cancer treatment.

Material and Methods: A total of five non-small cell lung cancer patients with tumours under 5 cm in size undergoing stereotactic body radiotherapy were recruited for this study. A planning 4DCT with 3 mm slice thickness was acquired for each patient using a belt system and retrospectively sorted into 10 bins, each assumed to estimate the actual size of the target in ten respiratory phases. Three of these bins representing end inhale, end exhale and mid-cycle, along with the motion encompassing maximum intensity projection (MIP), were contoured on axial slices by a radiation oncologist using the Computation Environment for Radiotherapy Research (CERR) platform (default lung window). The same patients were scanned using a Philips 3T MRI on a single 20 mm sagittal slab using a balanced SSFP sequence (TE/TR = 1.1/2.2ms, Pixel Size 3x3mm, 4fps) with the patient undergoing free breathing for 3 minutes (650 images). A radiation oncologist, using the CERR platform, with the default MR window, contoured these 650 sagittal